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A Strategic Model of Innovation

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Abstract

The academic literature provides many models of the innovation process, often based on the ‘innovation funnel’. Experience from earlier research has shown that these models struggle to define innovation as a process at the strategic level or provide ways to measure innovation effectiveness. A strategic model of innovation was developed to address this gap based on the methodology International DEFinition method (IDEFØ). Modelling innovation as a hierarchical, standardized process conforming to the strict discipline of IDEFØ resulted in an improved understanding of the innovation process. It enabled a more robust measurement of the company-wide impact of innovation support activities; in this research case measuring the benefits of adopting TRIZ tools.

Since the original work, this strategic model has been applied to diverse fields including Fast Moving Consumer Goods (FMCG), Automotive, Agriculture, Fisheries, City Planning and Sustainability. Learning from these experiences has informed refinements to the model such that it now provides a coherent, top-level understanding of innovation as a strategic process.

The key takeaway is that innovation is more than introducing new products and services; it is closely aligned to business strategy, encompassing all business activities. The proposed innovation model emphasizes the importance of intangibles. It also addresses the contradictions inherent in embedding sustainability within business and in society more widely. A valuable benefit of the proposed model is that it contextualizes discrete innovation programmes within a holistic framework. This paper describes the model and its practical application in framing Systematic Innovation programmes including TRIZ and TrenDNA. An example is provided, asking the strategic question - is the world really transitioning to electric vehicles, and if so, when?

Keywords: Business Strategy, Electric Vehicles, IDEFØ, Innovation Model, Sustainability

1. Introduction

Avon Vibration Management Systems (now DTR VMS) is a world leader in automotive elastomeric chassis and engine mounting systems, with several world firsts. Engine mounting systems manage loads, articulation/travel and vibration isolation under extreme working conditions.

In 2004 a research collaboration between Avon VMS and the University of Bath aimed to introduce TRIZ as a methodology to improve innovation (Frobisher, 2010). In common with automotive industry practice, the company used Six Sigma as an improvement philosophy. Projects were conducted within the DMAICT framework (Define, Measure, Analyse, Improve, Control, Transfer). This prompted the question – how to Define and Measure innovation?

Definitions of innovation found in literature were centered around various wordings and interpretations of 'the commercial application of new inventions'. Whilst this was obvious, the DMAICT approach for process improvement requires more than a top-level description of the process – the 'what'. It requires a comprehensive understanding of the process itself – the 'how'. This necessitated a review of detailed innovation process definitions and models. These were found to be overly focused upon ideation, creativity and invention and unsatisfactory for the purpose of the project. A suitable innovation process model was therefore unavailable, and one needed to be created.

This paper describes a model of innovation, based on the IDEFØ modelling approach, that was derived and applied during the project with Avon VMS. The benefits of using this comprehensive innovation model to guide innovation activities are discussed, and the potential benefits for TRIZ and Systematic Innovation practitioners identified. The application of the model is demonstrated through a case study of innovation in the electric vehicle market.

The novel contribution to the body of knowledge that this paper contributes is that:

•The innovation process can be decomposed into hierarchical functions

•Innovation sub functions are shown to transcend departmental and even inter-company boundaries

•The IDEFØ model of innovation is scalable from the company level to entire economic sectors

•The IDEFØ model supports the TRIZ approach to innovation, identifying contradictions

•Innovation is a holistic process that includes operations and end use of the product or service

Section 2 of this paper provides an overview of typical innovation models, grouping them in the domains of design and management. Section 3 is an introduction to the IDEFØ methodology. Section 4 applies IDEFØ to the innovation process with an example applied to the electric vehicle market. Section 5 discusses the implications of the work and Section 6 draws conclusions and recommendations for further research.

2. Typical models of innovation

The existing innovation literature was reviewed in order to identify relevant models of the innovation process. Models were identified from two different domains: the design domain, and the management domain.

Starting with the design domain, a commonly cited model of the innovation process was developed by the UK Design Council (2007), which is known as the 'double diamond' – shown in Fig.1. The model splits the innovation process into four phases that alternate between divergent exploration and convergent activities. Significant emphasis is placed on developing a better understanding of the problem through the 'discover' and 'define' phases, such that a precise problem definition and design brief can be formulated. The 'develop' phase then explores the potential solutions to the defined problem, before a final solution is selected and introduced in the 'deliver' phase.

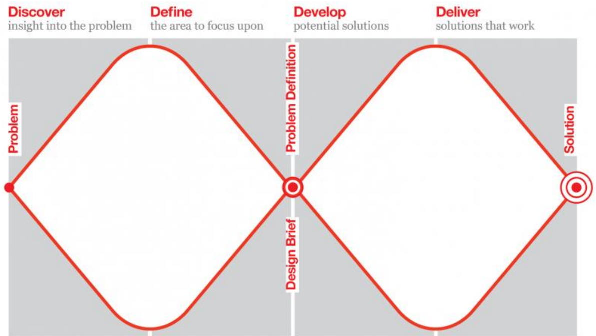

Fig. 1 Double diamond model of the innovation process (Design Council, 2007).

Another widely cited innovation model is 'design thinking'. Popularized by the Stanford d.school, this model, shown in Fig. 2 shares similarities with the double diamond model in terms of the overall process, but places more emphasis on understanding the user of the product or service in the 'empathize' phase, as well as on prototyping and iterative improvement of the design during the development of the final solution.

The influence of the design thinking process model and key principles can now be seen outside of the design domain, in areas such as information technology and business management, Dorst (2011).

These models, which represent innovation as a sequential process, have proven popular with innovation practitioners, which may be because they represent the innovation process as experienced at the operational level i.e. as a series of activities that each help to progress towards the completion of a defined, discreet 'project'. However, the limitation of these innovation models is that they do not provide a complete overview of the factors that influence innovation activity as a strategic business process.

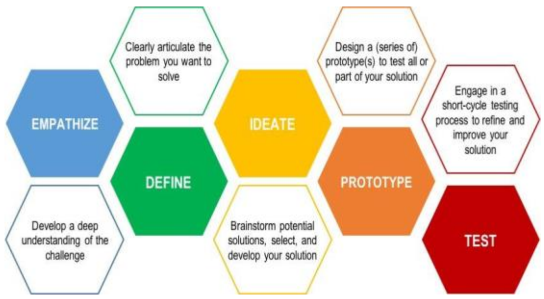

Fig. 2 'Design thinking' model of the innovation process (Brown.T , 2009).

Looking next at the models of innovation from the management domain, the model presented by Tidd et al. (2005), shown in Fig.3 is typical of the management perspective of innovation. Whilst the core process of 'search, select, implement' is very similar to the sequential models from the design domain, there are key additions. For instance, the strategic context of the organization is now explicitly represented as an influencing factor. Also, the importance of learning and improvement over time is shown, with the idea that the organization is progressing towards becoming an 'innovative organization'. Hence, from the management perspective, there is less emphasis on the individual project, and more emphasis on the activities and performance of the whole organization.

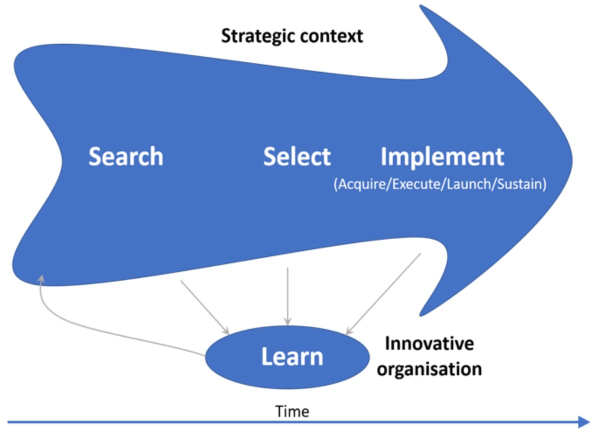

Fig. 3 Typical model of the innovation process from management domain (Tidd et al, 2005).

This more holistic view was a key aspect of the work by Stafford Bear in 1960s, who developed the 'Viable System Model' (VSM) as part of his cybernetic theory of organization, Bear (1972). VSM was intended to help describe all aspects of an organisations activities, including innovation. The model, shown in Fig.4 proposes five essential 'organs' that make up any autonomous, self-sustaining organization: the operational organ (S1), the coordinator organ (S2), the controller organ (S3), the planner organ (S4), and the policy organ (S5).

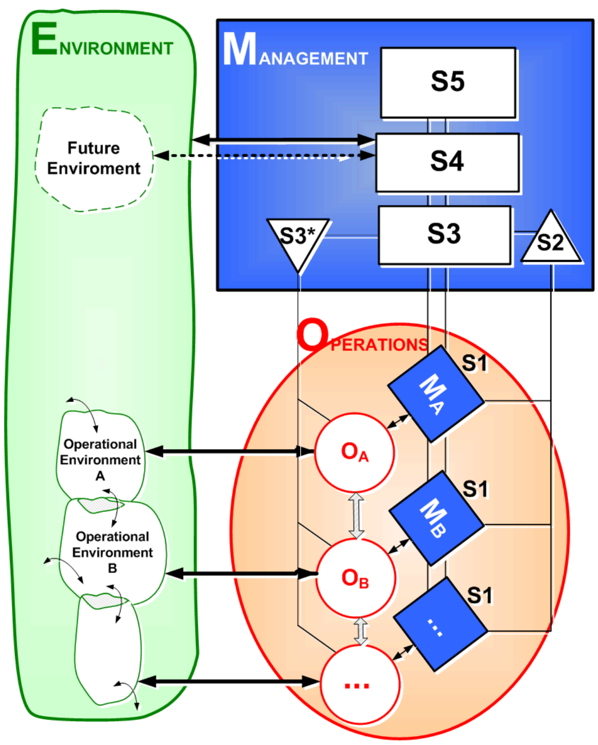

Fig. 4 Viable System Model of the organization (Bear, 1972)

Key aspects of VSM include an emphasis on the interaction between the organization and the external environment, the need to predict and respond to future changes, and the need for communication between all functions to ensure the success of the system. Whilst VSM provides a comprehensive and holistic model of the organization, it is perhaps more theoretical and less intuitive or practical as a support to inform and guide innovation activities.

What this brief review has shown is that the models of innovation from the design domain offer a practical, project-based perspective of the innovation process but typically do not sufficiently consider the context of the project in terms of the wider organization or the external environment and do not consider the changes that occur within them. These elements are considered to some extent in the innovation models from the management domain, but none of the existing models incorporate all of these elements and present them in a way that offers practical guidance or insight that can help innovation managers. The aim of this paper is to address this knowledge gap by applying the IDEFØ modeling approach to develop a comprehensive and practical model of innovation.

3. Introduction to the IDEFØ method

IDEFØ is a functional modelling approach developed by US Air Force Materials Laboratory in the 1970's. In the 1980's it was used to model the US military supply chain. Any process can be modelled using the IDEFØ convention, 'ICOM' – Inputs, Controls, Outputs, Mechanisms.

According to the method, verbs/functions are contained in boxes and are fed by arrows which are nouns – things, including data and information as well as physical objects and substances, as shown in Fig 5.

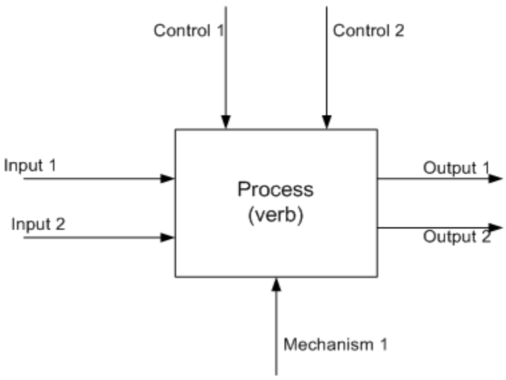

Fig. 5 IDEFØ ICOM process box.

Inputs are transformed or consumed by the process - e.g. raw materials, data or energy

Controls specify the conditions for the process to produce the correct output

Outputs are the data or objects resulting from the process.

Mechanisms are the means and resources which support the process.

Each process can then be decomposed into sub processes at increasing levels of detail in a hierarchical structure as described in Fig. 5.

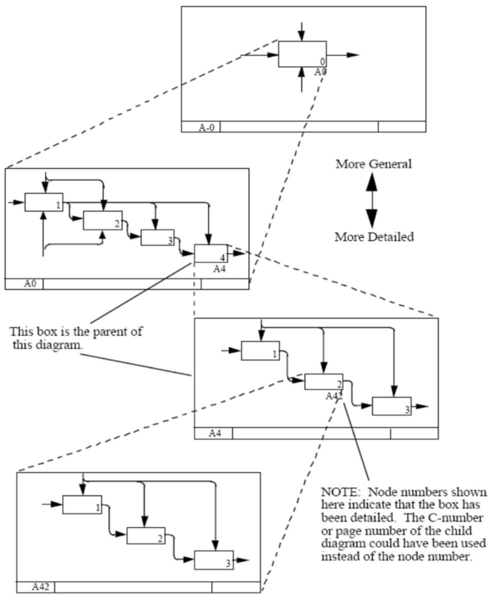

Fig. 6 IDEFØ decomposition model structure (KBSI, 2005).

The A-0 level enables the modeller to communicate the context of the system, and the A0 diagram shows the top level of the process (the reader is directed to note the distinction between 'A-0' and 'A0'). The decomposition of the boxes also applies to the arrows, which sub divide at lower levels – so 'data' may comprise invoices, schedules, designs and so forth at lower levels. The arrows into and out of a lower level box must remain consistent with the arrows at the higher level.

It is also important to note, that in common with the 'organs' of the Viable System Model shown in Fig. 4, processes are not strictly sequential, although they can be considered in this way. It is more akin to looking a circulatory or nervous system. This contrasts with the sequential mindset of the design paradigm of innovation.

The IDEFØ modelling approach promotes deep questions about the nature of processes, expanding the mindset outside of departmental structures; with a TRIZ-like focus on function. In the next section, we apply the IDEFØ modelling approach to the innovation process.

4. An IDEFØ model of innovation

The IDEFØ method requires that each box contains a verb that describes a process. 'Innovate' is a verb and is therefore a valid process for IDEFØ definition and modelling.

At the highest hierarchical level, Fig. 7 is the A-0 context diagram for the 'innovate' process, showing the top-level inputs, outputs, controls and mechanisms.

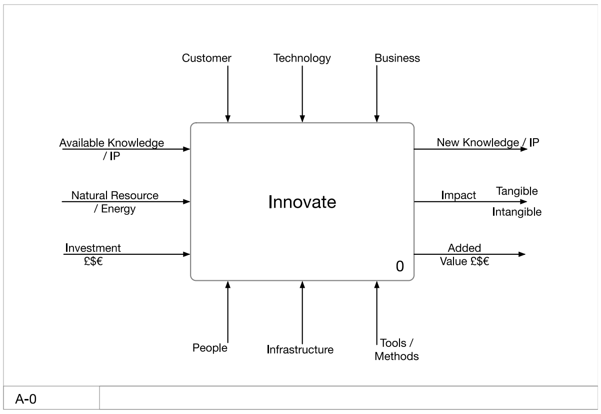

Fig. 7 Innovation A-0 context diagram

There are three categories of inputs: available knowledge and Intellectual Property (IP), natural resources including energy, and investment. Through the innovation process, these inputs are transformed into the outputs of: new knowledge and IP, impact (tangible and intangible) and added value. Of these outputs, it is the impact aspect that merits further discussion.

Typical models of innovation tend to focus on the tangible outputs of a single innovation project in terms of the new products/services delivered and the monetary added value for the business. In this IDEFØ model, the term 'impact' is used to encompass both these tangible impacts as well as the intangible. Furthermore, it is important to consider all impacts of an innovation process, both positive and negative. This broad definition of impact leads to categorization and examples of 'impacts' shown in Table 1.

Table 1 Innovation output – impact.

Positive Tangible	Positive Intangible
• Increased sustainability • Satisfied customer needs (jobs done) • Products performing safely and to specification • Improved health, safety, wellbeing • Increased wealth and financial security • Economic stability • Employment	• Societal benefit • Pride, surprise, delight, WOW! • Happiness, contentment • Love, acceptance, belonging • Nostalgia • Feeling 'in on things' • Sense of progress • Good reputation • Meaning
Negative Tangible	**Negative Intangible**
• Carbon footprint • Environmental pollution, contamination • Waste, faulty goods or services • Harm, risk to people (customers or employees) • Unsustainable consumption • Financial – expense • Economic disruption	• Societal Harm – e.g. unintended consequences • Shame, embarrassment • Fear, shock • Hate • Anger, rage • Frustration • Bad reputation • Injustice

The outputs in Table 1 are by no means comprehensive. TRIZ practitioners will notice a similarity with the ideality equation; with positive outcomes set against costs and harms. Good innovation output means more good things and less cost and harm, achieved by breaking contradictions – for instance reduced environmental impact whilst simultaneously satisfying consumer needs.

The mechanisms of innovation (sometimes referred to as 'means'), include 'people', 'infrastructure' and 'tools/methods'. People are the primary means of innovation and, as we shall see in the next section, 'people' includes those in the supply chain, at all levels and functions of business, and customers/consumers. This is in contrast with the prevailing assumption that innovation is conducted by designers, scientists, engineers and marketers.

People require an infrastructure to work within – buildings, machines, software, communications, transport and includes the supply chain.

People also require tools and methods to efficiently organize. This includes management systems and methodologies, innovation tools such as TRIZ, production process improvement tools such as Six Sigma and Lean, and physical test methods such as validation test protocols.

Finally, considering controls, there are three sources of requirements and constraints that together shape the outputs of an innovation activity. These are 'customer', 'technology' and 'business'. The importance of understanding customer needs - whether explicitly expressed or implicit/unconscious - is exemplified by the design and business innovation paradigms and marketing disciplines. Even 'new to the

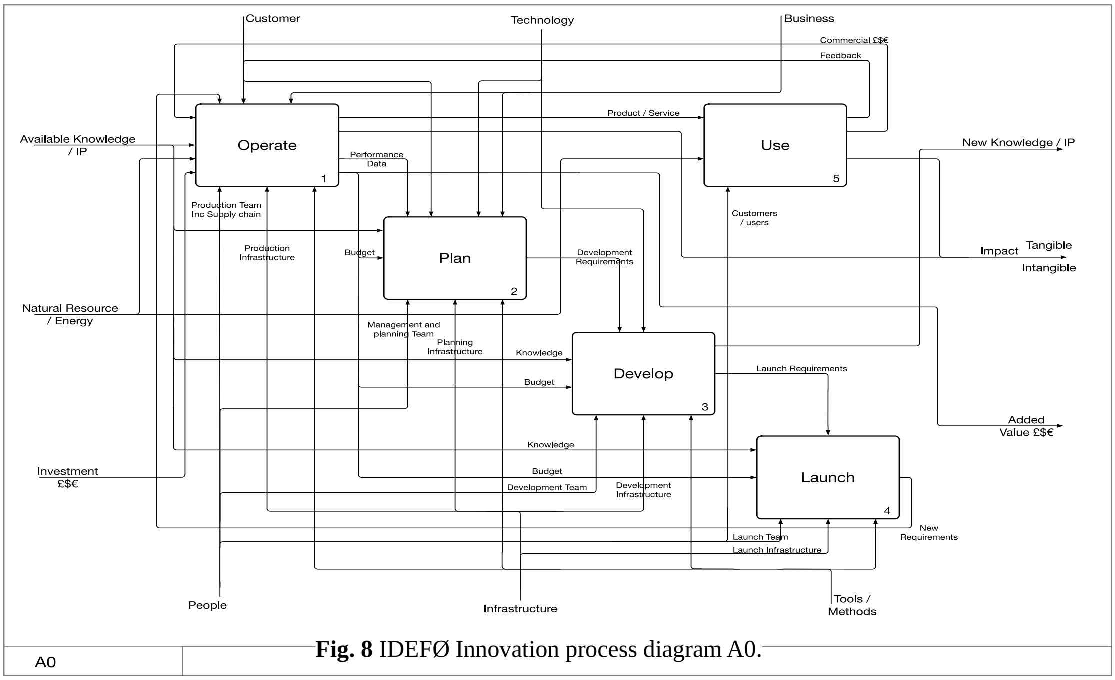

Fig. 8 IDEFØ Innovation process diagram A0.

world' products will make use of existing technologies (such as production technologies) and must therefore take account of the limitations and constraints that those existing technologies impose. These 'technologies' can be categorized within the domains of Physics, Chemistry, Biology and IT/communications. The business performing the innovation activity also generates a number of constraints, such as the need to comply with regulatory requirements, meet legal obligations or satisfy the overall strategy of the business, which may be to make strategic moves in relation to competitors or deliver an exit strategy.

So far, at the A-0 context level, the range of issues addressed by the IDEFØ model of innovation show considerable overlap with those covered by the typical models of innovation described in Section 2. The main novelty of this approach to understanding innovation is that managers should consider the tangible and intangible, positive and negative impacts and not just the product delivered and the financial added value. However, it is when we dig down into the next level of decomposition that we start to unearth some interesting insights.

Fig. 8 shows the A0 IDEFØ diagram for the 'innovate' process, which reveals the sub-processes and the next level of connecting arrows (not all arrows shown). The main sub-processes are 'operating the business', 'planning the business', 'developing new things', 'launching new things', and 'use of the product or service'.

The design paradigm models of innovation tend to focus on processes Plan, Develop and Launch. In contrast, the IDEFØ model brings in processes Operate and Use into the innovation process context.

Operation provides the finance to support everything else. Even in a start-up, it is an operational process to secure investment. In established companies the organization must decide what proportion of the financial output of the operations function should be taken as profit (added value) versus developing, improving and implementing new processes within the operations function, as well as new products and services. This is a strategic decision.

Other than investment or external funding, Operation depends on receiving money from customers, and therefore Use comes within the innovation process. Again, this is a point of difference with the typical view within both design and business paradigms that customers are external to the innovation process.

In practical use of this model, it has been found that the sub-process boxes hold true at any organizational scale. It holds at the level of a department, business unit/profit center, industrial sector or even at the national governmental level. It can therefore be considered generic. The hierarchical level context becomes more specific when considering the arrows.

When using IDEFØ to represent an innovation activity, modelers have to use judgement so as to present the IDEFØ diagram in a suitable manner for the context and purpose of the work. Whilst all flows of knowledge, resources and investment can in theory be represented, it is better to focus on the most important. Even with some pruning, Fig. 8 serves to demonstrate the many interlinkages between the sub processes and why innovation is such a complex process to manage; encompassing so much of what an organization does. We cannot go into the detail of each arrow, but discuss some key insights from Fig. 8 here.

Who does innovation? The traditional view would be those contributing to the Plan, Develop and Launch processes. But this is the wrong question. The model shows that it is not individuals but the organization that does innovation. The right question is "Who contributes to the innovation process?" And that is everyone – including the operations function and customers. The People arrow subdivides into the operations team, the planning team (often senior managers), the development team (specialists, technical and marketeers), and the launch team (mixture of project managers, technical and production/operations people). Finally, there are the customers and end users on which the whole innovation system depends.

From a traditional innovation managers perspective, the takeaway is that many of the people that affect innovation are outside of your direct control, and some you don't even know about - particularly in the supply chain and end customers. Hence, the spectrum of disciplines, perspectives, priorities and personality types required to successfully manage and deliver innovation is extremely diverse and often contradictory. This perhaps explains why so many innovation attempts fail.

Another interesting insight is that the Impact is influenced by the nature of the operations and the end use of product and service. The tangible dimension includes, for instance, the environmental impact of the production facilities, including the supply chain right back to the mine or farm. Sourcing and purchasing strategy can be influenced by organisations to minimize negative imp acts, but also the innovation process itself can seek to balance or break the contradictory requirements of innovation controls – consumer needs, technology, and the businesses financial realities, regulatory/legal and competitive landscape. It is also important to note that the way customers use and dispose of a product is part of the responsibility of the innovation process which represents an innovation challenge in itself.

From this brief introduction, it is clear that applying the IDEFØ methodology to model the innovation process provides a model that is both comprehensive and also able to provide fresh insights and perspectives of innovation. The IDEFØ model can also be used to forecast future developments at a sector level. A case study has been developed of the IDEFØ model applied to the automotive sector, considering the transition to electric vehicles (EVs). The A-0 context diagram is provided in Fig. 9 whilst the full case study is available at: https://strategic-innovation.co.uk/electricvehicles.

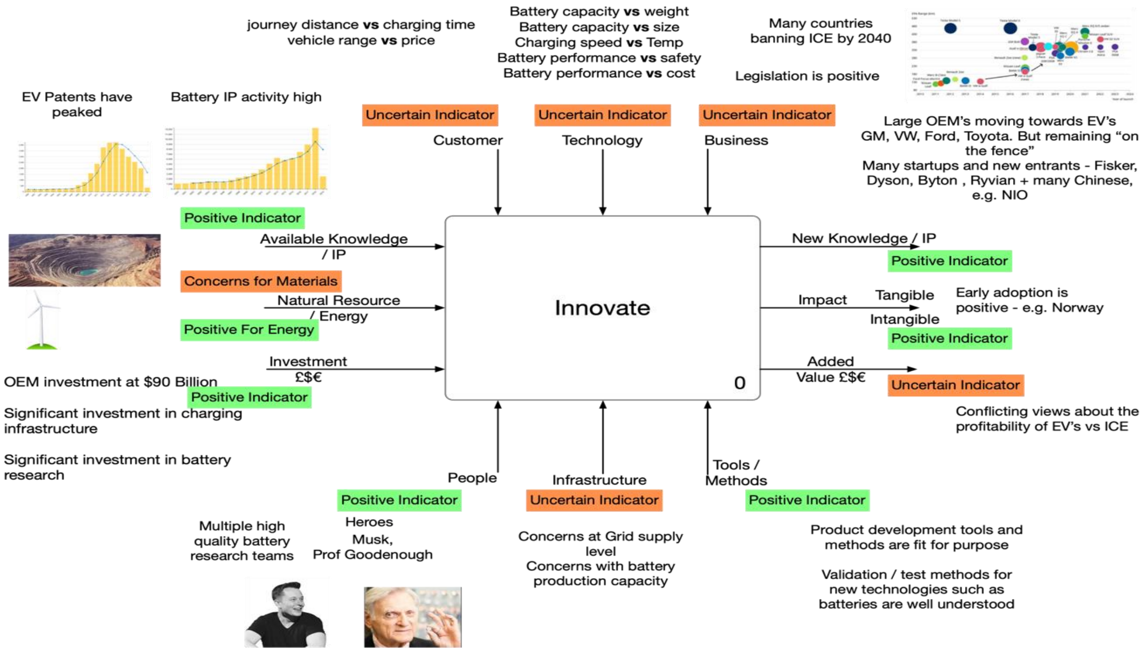

Fig. 9 Summary of the A-0 diagram applied to the context of EV adoption in the automotive industry.

In brief, the finding is that the most important contradictions to be solved for EV adoption are primarily within the battery domain. It appears that sufficient investment is going into solving the right problems such that, if resolved by the talented teams working in the area, it should flip the majority of the industry to producing full electric EV's, perhaps more quickly than some will be expecting.

Further recent publicly available examples of use of the IDEFØ model applied to the fisheries sector are available; Techau et al, (2020) and Sala Antonello et al, (2020).

5. Discussion

The majority of models for innovation and creativity, such as the double diamond or design thinking models, use a sequential approach to creation and management of ideas or concepts. These models are not wrong, and are powerful tools for their purpose, especially in understanding the voice of the customer. However, as evidenced in the original research, these do not sufficiently provide insight in the broader strategic setting because they are sequential not hierarchical.

Strategic models that are none sequential, such as VSM, tend to focus on the top level and are suitable for understanding the voice of the business for strategic planning, but are not suited as tools for management of innovation processes.

There appears to be a need for a model that can be both hierarchical and sequential. At the A-0 context level, the IDEFØ model is non-sequential and hierarchical. At the A0 level, the IDEFØ model can be both sequential and non-sequential. The IDEFØ model therefore offers a potential solution to this contradiction.

5.1 TRIZ / Contradictions

TRIZ theory emphasizes the importance of resolving contradictions to solve the right problems. There are TRIZ based approaches for each of the IDEFØ A-0 controls – TrenDNA (Mann, 2009) for consumer, Classical TRIZ for technology and Business TRIZ for business. The competing and conflicting requirements that emerge from these three different perspectives can be viewed as a source of contradictions by the TRIZ practitioner. As an example, taking price, we can see that there is a contradictory requirement for the business to seek a high price, conflicting with customers who require a low price. This contradiction can be solved by applying inventive principles or evolutionary trends to resolve technical challenges, enabling maintenance or enhancement of the functions that customers require to be delivered, whilst using fewer inputs thus reducing costs.

5.2 Measuring Innovation

The IDEFØ model could potentially be used to refine approaches to measuring innovation. One approach would be to measure the ratio of inputs to outputs – the size of the jump. How effectively does the organization gather and manage available knowledge/IP and transform this into new knowledge/IP? How well does the organization turn investment into added value? How effectively does the system, including the supply chain and end users, turn natural resources and energy into tangible benefit? Existing approaches appear reasonably well established to measure these tangible outputs/ratios. The primary gap appears to be measuring and understanding intangible output.

It is a common criticism of the capitalist system, that businesses put profit above everything. The reader may agree or disagree with this premise depending upon where on the political spectrum they sit. However, what should be agreed is that one reason this may be true is that money is easier to measure than emotion. Steve Jobs is famously quoted as saying, "I want to put a ding in the universe". In common with many entrepreneurs, such as Elon Musk, Jobs wanted to make a difference and leave a lasting legacy – a positive innovation footprint, which is far more than a purely financial motive.

Intangible impacts are currently the domain of marketeers - branding and market research. However, the wider reputation of the organization, within society, politics, media and industry is not fully addressed as yet within the innovation strategy community. The unintended societal consequences of advances in technology do not seem to be responsibly considered or even understood, never mind addressed. This is evidenced by the debate concerning social media and its effect at the individual level (in terms of mental health) and at the societal level (in terms of political influence).

Fortunately, the science of measuring intangibles is developing. Software based approaches such as Pansensic (www.pansensic.com) are making substantial progress in this area – being able to map and track emotional content such as frustration, fear, delight and love.

Companies that are interested to learn more about the legacy they are building and their intangible impacts should ask themselves the question: "if we were to delete our company, would we be missed?" Being able to track how such intangible aspects of Impact change over time may allow leaders to steer organisations using more than the existing financially skewed performance indicators.

5.3 Sustainability

There is an increasing urgency to address global environmental challenges. The IDEFØ model emphasizes to individual companies that their innovation impact (footprint) includes their direct environmental impact but that they also have a responsibility to manage the impacts of their supply chain and the behavior of customers.

The hierarchical approach of the IDEFØ model also allows analysis at the industrial sector level, giving policy makers an insight into the nudges and frameworks required to successfully align the value-add financially oriented output arrow with sustainability objectives.

5.4 Managing Innovation

Insights related to tackling relevant contradictions and managing knowledge have already been covered in this paper. From experience, most companies are not short of great ideas, the issues are the selection and combination of the right ones and implementing them effectively.

Project managers will testify that introducing new products and processes creates a tension, or even outright interdepartmental warfare, between the operations teams of process 1 (Operate) and those of process 4 (Launch). Perhaps this is at least partly because operations, in many companies is considered separate to the innovation team, and is set up, financed, measured and managed accordingly. Organisations need to find better ways to unite the entire enterprise within the innovation framework. Everyone in an organization contributes to innovation in some way, whether they realize it or not. This perspective appears to be relevant to the subject of 'innovation capability'; managing systems to be able to successfully make step changes either as a leader or follower in a given marketplace. See fig. 10

At the sector level, the introduction of new things, tends to require the destruction of something to make room – 'creative destruction'. The challenge therefore is to introduce 'managed destruction' – ideally by designing markets and sectors that are set up to renew themselves with minimum overall harm. Companies need to plan for step change disruption, as opposed to steady state or incrementalist thinking. This includes considering financial models, workforce skills/flexibility and how they co-operate and compete with other players.

Innovation models from the management domain such as VSM are used to develop strategy, Hoverstadt, (2017). In contrast, design paradigm models suggest that innovation projects are discrete activities that contribute to a given strategic direction. The IDEFØ model indicates that the innovation process itself has a much wider scope than that of the design paradigm and shares a similar scope to VSM. A key insight from this research therefore, is that the innovation process could be considered closely synonymous with strategy.

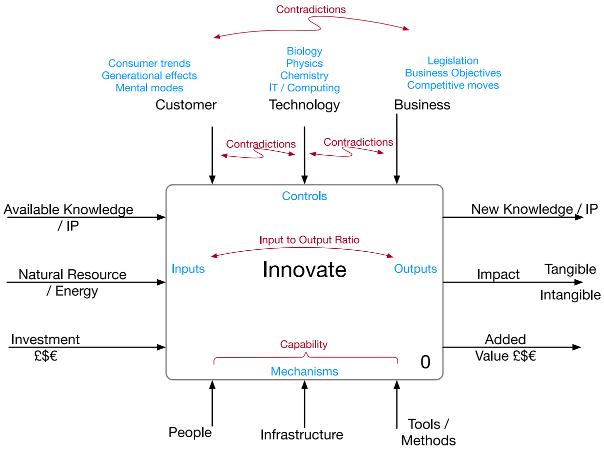

Fig. 10 Summary of the A-0 context diagram applied to measuring and managing innovation.

6. Conclusions

This paper started out by identifying the range of existing models of innovation identified within the design and management communities. Some models from the design domain provide a sequential view of the innovation process and are good at showing the main activities of innovation but do not show the strategic or contextual influences. Models from the management domain address the strategic context but are too abstract to be of real benefit to practitioners. It was proposed that a model of innovation based upon the IDEFØ modelling approach could address this gap.

Through the presentation of the generic IDEFØ model of innovation and its application to a case study, it has been shown that the IDEFØ innovation model offers the potential to harmonize the sequential, project based innovation models of the design paradigm with the hierarchical models from the management domain. Key insights from the application of the model include the idea that innovation has a wider scope than is traditionally assumed – and includes operations, supply chain and end users and that all 'people' within the system, including employees, suppliers, customers, regulators etc. contribute to the innovation process. More generally, the model raises the idea that because of this wider, holistic definition, the innovation process is closely synonymous with strategy.

Within the innovation consulting activities of the author, the practical application of this model so far has been to create an appreciation of the connected nature of innovation programmes at clients and how everything fits together. It has also proved useful in developing a holistic view of an economic sector to estimate the propensity for a disruptive 'jump' – as demonstrated in the electric vehicle case study.

Future research activities that may benefit from adopting the IDEFØ model of innovation might include studies concerned with the measurement of innovation attempts relating to the broad definition of innovation 'impacts' provided by this model and the ability to apply the model at different systems levels (e.g. business units, whole companies or whole industries). The model could also be helpful as the basis for a study of success and failure factors for innovation, as the ability of the model to represent the innovation activities of a company in a comprehensive manner should ensure that all aspects (both internal and external to the company) are considered. Finally, the implication of this research to the alignment of sustainability and circular economy objectives with business strategy and product development should be further considered.

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